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ABSTRACT

Air Pollution and Infant Mortality: Evidence from the Expansion of Natural Gas Infrastructure*

One of the consequences of rapid economic growth and industrialization in the developing world has been deterioration in environmental conditions and air quality. While air pollution is a serious threat to health in most developing countries, environmental regulations are rare and the determination to address the problem is weak due to ongoing pressures to sustain robust economic growth. Under these constraints, natural gas, as a clean, abundant, and highly-efficient source of energy, has emerged as an increasingly attractive source of fuel, which could address some of the environmental and health challenges faced by these countries without undermining their economies. In this paper, we examine the impact of air pollution on infant mortality in Turkey using variation across provinces and over time in the adoption of natural gas as a cleaner fuel. Our results indicate that the expansion of natural gas infrastructure has caused a significant decrease in the rate of infant mortality in Turkey. In particular, a one-percentage point increase in the rate of subscriptions to natural gas services would cause the infant mortality rate to decline by 4 percent, which could result in 348 infant lives saved in 2011 alone. These results are robust to a large number of specifications. Finally, we use supplemental data on total particulate matter and sulfur dioxide to produce direct estimates of the effects of these pollutants on infant mortality using natural gas expansion as an instrument. Our elasticity estimates from the instrumental variable analysis are 1.25 for particulate matter and 0.63 for sulfur dioxide.

JEL Classification: I0, I12, I15, I18, O10, O13, Q42, Q48, Q53

Keywords: air pollution, infant mortality, environment, natural gas, coal, Turkey

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I. Introduction

The pressure to industrialize and become competitive in the global economy has often sidelined concerns over environment and air pollution in much of the developing world. Moreover, consumption of coal, which produces far more carbon emissions than any other fuels, has risen by nearly 60 percent between 2000 and 2010, driven primarily by the surging demand in developing economies (International Energy Agency, 2013). Consequently, air pollution presents a formidable threat to some of the gains in health outcomes, such as infant mortality, achieved by the developing world over the last several decades. According to the World Health Organization (WHO), air pollution is estimated to cause approximately 3.3 million deaths worldwide annually, mostly in developing countries, and a significant proportion of these deaths are in children under age 5 (WHO, 2011). The Organization for Economic Co-Operation and Development (OECD) predicts that urban air pollution would become the top environmental cause of premature mortality worldwide by 2050 (OECD, 2012). Developed countries, in contrast, have made substantial progress in improving their environmental conditions and air quality due to advances in cleaner technologies and stringent regulations. However, these countries may not be able to escape the negative effects of air pollution either as global circulation patterns can transport some types of pollutants around the world.

Despite growing concerns about the harmful health effects of air pollution in developing countries, most of the available evidence on the subject comes from the United States and other developed countries (e.g., Chay and Greenstone, 2003a, b; Currie and Neidell, 2005; Currie, Neidell, and Schmieder, 2009; Currie and Walker, 2011; Currie, Greenstone, and Moretti, 2011; Knittel, Miller, and Sanders, 2011). However, it is not clear whether estimates obtained in studies from high-income country settings could serve as a reliable guide to the impact of air pollution on infant health in developing countries, where baseline levels of air pollution are substantially higher (Arceo-Gomez, Hanna, and Oliva, 2012; Currie and Vogl, 2012).[1]

One explanation for the relative paucity of evidence from developing countries is the fact that policy changes and environmental regulations in the developing world are rare and weakly enforced, failing to generate enough variation in air pollution levels to detect statistically significant effects (Arceo-Gomez, Hanna, and Oliva, 2012; Tanaka, 2012). In fact, the lack of sources of exogenous variation has been a major obstacle to producing credible estimates of the causal effect of air pollution on infant health for both developing and developed countries. This obstacle stems from the fact that pollution is not randomly assigned and differences in exposure are likely to be correlated with other determinants of health. Therefore, it is possible that the associations documented in much of the earlier research on air pollution and health may reflect the impact of omitted factors, such as socio-economic status, that are correlated with both pollution exposure and health outcomes.

Only recently, researchers have responded to this challenge and turned their attention toward identifying exogenous sources of variation that could yield the causal impact of air pollution on health in developing country settings. For example, Jayachandran (2009) studies the impact of particulate matter on infant health using variation in pollutants caused by massive wildfires in Indonesia. Tanaka (2012) uses variation in the regulations on emissions from power plants to examine the impact of air pollution on infant mortality in China. Arceo-Gomes, Hanna, and Oliva (2012) exploit the number of thermal inversions as an instrument to investigate the

[1] Arceo-Gomez, Hanna, and Oliva (2012) discuss a number of scenarios under which the estimates drawn from studies of developed countries may have limited external validity to a developing country context. For example, they suggest that estimates from developed countries may underestimate the effect in developing countries if the marginal changes in pollution are more damaging at higher levels of pollution. Alternatively, they argue that the estimates from developed countries may overstate the effect for developing countries since infants might already be weak and malnourished due to other negative health shocks.

impact of air pollution on infant mortality in Mexico City. Finally, Greenstone and Hanna (2011) examine the impact of air and water pollution regulations on infant mortality in India.

This paper extends the growing literature on air pollution and infant mortality in developing countries by using a novel source of variation from Turkey. In particular, we exploit the widespread replacement of coal by cleaner-burning natural gas for residential and commercial space heating and cooking in Turkish provinces, which has been made possible by the expansion of a network of natural gas pipelines originating from Russia in the 1980s.[2] Burning of natural gas emits virtually no sulfur oxide, which is a key component of acid rain. Emissions of total particulate matter, carbon monoxide, and nitrogen oxide, which cause acid rain, smog, and contribute to global warming, are also at much lower quantities from burning of natural gas compared to burning coal. First introduced to households and businesses in Ankara in 1988 and followed by Istanbul and Bursa in 1992, the number of provinces with natural gas has grown rapidly over the last two decades. As shown in Figure 1, 61 of the 81 Turkish provinces now have access to a natural infrastructure. On the one hand, the expansion of natural gas networks in Turkey has caused considerable improvements in air quality by reducing emissions of pollutants such as particulate matter, sulfur dioxide, carbon dioxide, and nitrogen oxides. On the other hand, Turkey has also experienced significant reductions in infant mortality rate during the same period. For example, between 1990 and 2010, infant mortality rate (per 1,000 live births) decreased from 33 to 10. In fact, Turkey has already surpassed one of the Millennium Development Goals, which called for a reduction of the under-five year old mortality rate by two thirds between 1990 and 2015. Nonetheless, Turkey still has the second highest infant mortality rate among the OECD countries after Mexico.

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[2] Natural gas is considered the cleanest energy source among all fossil fuels. Burning natural gas as opposed to other fossil fuels emits fewer harmful pollutants, and an increased reliance on natural gas can potentially reduce the emission of many of these most harmful pollutants (U.S. Environmental Protection Agency, 2012).

There are several explanations offered for the pathways through which prenatal exposure to air pollution can affect infant health. For example, it has been suggested that exposure to pollutants like carbon monoxide and particulate matter could lead to impaired fetal tissue growth through oxygen deprivation (Ha et al., 2001; Dejmek et al., 2000; Maisonet, Correa, and Jaakkola, 2004; Siddiqui et al. 2008; Li et al., 2003). The effects of air pollution can be damaging particularly for young children, whose lungs are not developed and immune systems are weak. It is also argued that air pollution can harm the infant through adversely affecting the health of the pregnant mother, for example, by weakening her immune system, which could then be detrimental for her fetus (Currie, Neidell, and Schmieder, 2008). Furthermore, prenatal exposure to potent atmospheric pollutants such as polycyclic aromatic hydrocarbons, released by the combustion of coal, has been linked to poorer birth outcomes, lower birthweight and smaller head circumference (e.g., Perera et al., 1998; Dejmek et al., 2000; Choi et al., 2006).

Our paper makes several contributions to the literature on the impact of air pollution on health. First, we provide evidence on the effect of air pollution on infant mortality from a rapidly growing developing country, which has not been studied previously. Second, we exploit a novel source of variation, i.e., the expansion of natural gas infrastructure. While the effect of natural gas use on infant mortality is interesting in and of itself, we also utilize the variation in air pollution generated by this development to produce direct estimates of the impact of air pollution on infant mortality. Unlike most previous studies that rely on policy changes measured as binary variables, our treatment is in essence a continuous variable, thereby allowing a dose-response relationship between changes in air pollution and infant mortality. In particular, we not only exploit the variation in the timing of the introduction of natural gas across provinces over time, but also utilize the variation in the rate of expansion of natural gas services, measured by the number of subscribers to natural gas services per 100 persons. As shown in Figure 2, the natural gas infrastructure has grown rapidly in Turkey between 2001 and 2011, but the transition is far from complete. For example, in 2011, there were 11 natural gas subscribers for every 100 persons in provinces with a natural gas infrastructure.[3] About half of the natural gas imported in Turkey is used in power plants to produce electricity. The share of natural gas used by households and the industry is about 20 percent each (Botas, 2010). Third, by focusing on province level air pollution and infant mortality, our analysis implicitly allows for households which decide to switch from coal to natural gas to be different from those which do not in both observable and unobservable ways, enabling us to focus on an intent-to-treat effect.

Finally, studying the impact of natural gas is an important and a timely matter because, as a cleaner, abundant and highly-efficient source of energy, natural gas has increasingly emerged as a bridge fuel toward the eventual replacement of carbon-based fossil fuels by renewable energy sources (Podesta and Wirth, 2009; Paltsev et al., 2011). On the one hand, the mounting energy demand by emerging and developing economies like Brazil, China, Indonesia, Mexico, and Turkey presents a serious challenge against efforts to address global climate change. On the other hand, reducing emissions through environmental regulations does not seem to be a viable option in the near future because of steadfast refusal by many of these countries to committing to legal obligations and setting emissions targets. There are also challenges to effective enforcement of regulations due to weak governance, not to mention the costs induced by

[3] Natural gas subscribers include both households and businesses. Assuming that there are roughly four persons per household and one business establishment per 10 persons, the maximum number of household and business units with natural gas could be 35 per 100 persons. Then, 11 subscriptions per 100 persons would correspond to a penetration rate of about 31 percent. Of course, there are vast differences across provinces in the distribution of the number businesses. In more urbanized provinces (e.g., Istanbul and Ankara), there would be a larger number of business establishments per capita and there may also be fewer people living per household. In that case, the maximum number of household and business units per capita with a subscription to natural gas services would be higher. For example, For instance, if there are 3 individuals living in per household and there are 2 business establishments for every 10 persons living in the province, the maximum number of household and business units with access to natural gas would be about 53 per 100 persons.

regulating emission levels and the corruption (Greenstone and Hanna, 2011; Jayachandran, 2009). Under these circumstances, natural gas serves an increasingly important function for efforts to reduce global carbon emissions, while allowing the developing countries to sustain their economic development without having to resort to strict regulations.[4] A number of studies have already considered the economic impact of the expansion in the natural gas infrastructure (Boxall, Chan, and McMillan, 2005; Shahidehpour, Fu, Wiedman, 2005; Jacquet, 2011; McMillen and Prakash, 2011). But a full account of the implications of this development also requires a thorough examination of its effects on environment and public health.

We begin with estimating a reduced form model to document that the penetration of natural gas services across provinces over time has caused a significant reduction in infant mortality. In order to account for omitted variables that could be correlated with both the expansion of natural gas networks and infant mortality, we control for various time-variant province characteristics in our models. Furthermore, we include province and year fixed effects along with province-specific linear and quadratic time trends as well as region by year fixed effects in our empirical models. Our estimates indicate that a one-percentage point increase in the rate of subscriptions to natural gas services would result in a 4 percent decline in infant mortality rate, which could translate into approximately 348 infant lives saved in 2011 alone. Next, we show evidence that the reductions in infant mortality associated with the penetration of natural gas services are driven by the improvement in air quality. In particular, we use supplemental data on total particulate matter and sulfur dioxide available for a sub-period of our analysis to produce direct estimates of the impact of improved air quality associated with the

[4] Natural gas is playing an increasingly significant role not only for Turkey but other major economies including China, Brazil, and India (e.g., Jiping, 2010; DeShazo, Ladislaw, and Primiani, 2007; U.S. Energy Information Administration, 2011).

adoption of natural gas on infant mortality. Our elasticity estimates from this instrumental variables analysis are 1.25 and 0.63 for particulate matter and sulfur dioxide, respectively.

The rest of the paper is laid out as follows. In Section II, we provide some information on the expansion of natural gas networks in Turkey. We then discuss our data in Section III and methods in Section IV, followed by the results in Section V. We provide a brief conclusion in Section VI.

II. Development of Natural Gas Networks in Turkey

The Turkish economy, currently ranked the 18th largest in the world, has undergone a major transformation over the last two decades. This transformation is marked by rapid growth and structural changes, such as privatization of state enterprises and integration into the European Union and the global economy. However, Turkey's emergence as an economic power has brought with it concerns on environmental and health degradation. Concurrent with the strong economic growth, energy use has increased sharply and energy related carbon emissions have more than doubled since 1990. According to estimates from the OECD, excessive SO_2 emissions in the early 1990s might have caused in excess of 3,000 deaths and restricted activity days of about seven million annually (International Energy Agency, 2005).

Turkey's recognition as a candidate for European Union membership in December 1999 and the accession talks that started in 2005 have brought the country's environmental record under increased scrutiny. This has led to the Turkish government putting a number of legislations and regulations in place to improve energy efficiency and address environmental concerns, including flue gas desulfurization requirements on all newly commissioned coal-fired power plants, new by-laws on air pollution control from heating in 2005, 2007, and 2009, the ratification of the Kyoto protocol, and setting a unilateral target for carbon emissions introduced by the 2009 National Climate Change Strategy (International Energy Agency, 2009). Furthermore, the use of leaded gasoline was banned in 2004. Note that all of these laws and regulations have been at the national level and enforced uniformly everywhere in Turkey.[5] While these measures have resulted in considerable improvements in air quality, emission standards in Turkey remain significantly less stringent than those currently in place in European countries.

During the same period, Turkey has also intensified its efforts to diversify its energy portfolio and ensure sufficient energy for its rapidly growing economy. These efforts have led to an expansion of natural gas networks across Turkish provinces, which have then facilitated the migration from coal to natural gas for space heating and cooking purposes by dwellings and businesses. Just between 2004 and 2007, licenses were awarded to private investors for building and operating "greenfield" gas distribution systems in 26 additional provinces.[6] Consequently, natural gas consumption has risen rapidly since the end of 1990s and the levels of SO_2 have declined markedly (Kaygusuz, 2007). While the number of households using solid fuel like coal has declined markedly, natural gas use has gone up.[7] Currently, 41 percent of households in Turkey rely on solid fuels (mainly carbon), while another 40 percent use either natural gas or hybrid systems that use both natural gas and solid fuels (Guide for Understanding Turkey, 2010).[8]

Turkey's close proximity to some of the world's largest natural gas producers has especially played an important role in assisting this migration toward natural gas. In fact, most

[5] Turkey has a centralized governmental system and laws are typically legislated and implemented at the national level.
[6] Number of provinces with natural gas infrastructure by year is as follows (2001 to 2004: 5 provinces; 2005: 13 provinces; 2006: 20 provinces; 2007: 31 provinces; 2008: 36 provinces; 2009: 54 provinces; 2010: 60 provinces; 2011: 61 provinces).
[7] For example, since 1990, the household consumption of coal has doubled while the consumption of natural gas has gone up by 142 times (350 Ankara, 2012).
[8] The remaining households use other types of energy, such as electricity and solar systems.

natural gas is travelled to Turkey via a natural gas grid, connected to several of its neighboring countries (see Figure 3). Together these pipelines have a capacity of 48.8 billion cubic meters (bcm). Over 60 percent of the natural gas used in Turkey is exported from Russia, which arrives in Turkey via two routes, first one coming through the Blue Stream pipeline that crosses the Black Sea and the other one traveling via the West Gas Pipeline through Bulgaria. The capacity of these two pipelines is about 30 bcm. Another pipeline with a capacity of 8.8 bcm is with Azerbaijan that travels through Georgia via the Baku-Tbilisi-Erzurum pipeline that was launched in 2007 (International Energy Agency, 2011). The third connection is to Iran with a capacity of 10 bcm of natural gas. In 2010, Turkey imported 38 mcm of natural gas, an increase of 8.6 percent compared to 2009. Pipeline imports accounted for 79 percent of this total, while the remaining 21 percent transmitted in liquefied form, mainly from Azerbaijan, Algeria, and Nigeria (International Energy Agency, 2011).

The gas industry is regulated by the Energy Markets Regulatory Authority in Turkey. Although the majority of the market is open to private competition, the industry is currently dominated by the state-owned Petroleum Pipeline Corporation (BOTAS), which also builds and operates gas pipelines in Turkey. The monopoly power of BOTAS over Turkey's natural gas market ended in 2007 with Shell becoming an important player in distributing some of the natural gas imported from Russia (Energy Information Administration, 2011).

According to statistics from the International Energy Agency, the total consumption of coal and peat in Turkey increased from 11 Million tons of oil equivalent (Mtoe) to 14 Mtoe between 2000 and 2010, while the total consumption of natural gas almost tripled from 4.9 Mtoe to 13.1 Mtoe during the same period (International Energy Agency, 2012). Similarly, the share of natural gas in electricity production increased from 37 percent in 2000 to about 46 percent in

2010. During the same time, the share of coal and peat has been relatively stable, exhibiting a small decline from 31 percent to 26 percent. Parallel to the fluctuations in the world markets, the natural gas prices for households has increased sharply during that period from 259.3 to 526.4 dollars per 10^7 kcal on a gross calorific value (International Energy Agency, 2011). In terms of residential use, the demand for natural gas exhibited an average increase of 28 percent between 1990 and 2009, while the demand for coal increased only by 3.6 percent (International Energy Agency, 2011). Similarly, the average annual increase in the industrial use of natural gas has been 10.6 percent compared to only 1.5 percent for coal during that period.

III. Data and Descriptive Statistics

Time-Variant Province Characteristics

We control for a vector of time-variant determinants of infant mortality in our empirical models. These variables are at the province level and include hospitals and hospital beds per 100,000 persons, percent with a high school degree, percent with a college degree, number of students per teacher in secondary schools, number of motor vehicles per 1,000 persons, unemployment rate, number of physicians per 100,000 persons, income per capita at the sub-regional level,[9] an indicator variable for whether the province has a Family Physician Program,[10] and an indicator variable for whether the party affiliation of the province's elected mayor is the

[9] According the Turkish Statistical Institute, Turkey is classified into 12 regions, 26 sub-regions, and 81 provinces. The Turkish Statistical Institute is the major governmental institute, which collects and processes data from a variety of different sources on numerous topics ranging from agriculture to health. See http://www.turkstat.gov.tr for more information.

[10] The Family Physician Program, aimed to provide primary care services to the needy, started as a pilot program in the province of Duzce in 2005 and was later expanded to all of the 81 provinces by 2010. http://ailehekimligi.gov.tr/english/index.php/general-information/family-medicine-in-turkey

same as the party governing Turkey.[11,12] Data on province level populations are obtained from the Turkish Statistical Institute from the Turkish Statistical Institute for years 2000 and 2007-2011 and from the Turkish Ministry of Health between 2001 and 2006.[13] Information on the Family Physician Program comes from the Ministry of Health. The remaining control variables are obtained from the Turkish Statistical Institute.

Table 1 shows the means and standard deviations for these characteristics. The first column presents the descriptive statistics for the full sample. The descriptive statistics for all province-year observations without access to natural gas are displayed in column (2) and those with access to natural gas are displayed in column (3). The descriptive statistics for the subsample of provinces that has never been introduced to natural gas during our analysis period are shown in column (4) and those that have gained access to natural gas at some point during that period are shown in column (5).

As illustrated in Table 1, provinces with and without access to natural gas differ from each other in a number of characteristics. For example, provinces with natural gas are more likely to have a mayor whose party affiliation is the same as the ruling party. This is not surprising in a country where the central government continues to maintain control over decisions on resource allocations and local investments. Provinces with access to natural gas also have higher number of motor vehicles, per capita income, hospital beds and physicians, individuals with college education, and population, in addition to a higher likelihood of having a family physician program initiated in the province by the government. Again these differences

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[11] In the period 2001-2011, Turkey had three general elections (2002, 2007, and 2001) and two local elections (2004, and 2009). The members of the Turkish Parliament are elected in general elections, and province and town mayors are elected in local elections.

[12] We create dummy variables that equal unity for observations with missing data on the explanatory variables.

[13] Since no Census was conducted between years 2001-2006, the province level population figures for the 2001-2006 are based on extrapolations implemented by the Ministry of Health. Alternatively, we imputed the population figures between 2001-2006 using province specific growth rates. Using these values produce results almost identical to those presented in this paper. These results are available from the authors upon request.

are indicative of the fact that natural gas penetration is more likely in provinces that are wealthier, more urban, and with more educated populations. On the other hand, there is no difference in unemployment rate between the two types of provinces.

Adoption of Natural Gas in Turkey

Data on natural gas variables come from the Dogal Gaz Dergisi (the Turkish Natural Gas Journal).[14] As shown in Figure 1, the number of provinces with natural gas infrastructure was only five in 2001. This number grew substantially in the following ten years and, by 2011, 61 of the 81 Turkish provinces had access to a natural gas infrastructure.[15] Note that there is considerable variation in the rate by which natural gas has expanded across provinces. To illustrate, we show the expansion of natural gas infrastructure for six select provinces, including Istanbul, Izmir, Bursa, Gaziantep, Kocaeli, and Erzurum in Figure 4. Note that the first four of these provinces are among the top ten in terms of population, while the last two are medium sized provinces. The figure shows that there is considerable variation across provinces both in terms of the year of adoption and the growth of the natural gas infrastructure.

As mentioned previously, natural gas is imported from mainly Russia and a few other countries through pipelines that are operated by the state owned company, BOTAS, and is transmitted to individual provinces by private distribution companies.[16] These companies are responsible for providing the public with clean burning natural gas by establishing and operating all infrastructural facilities for the utilization of natural gas. As shown in Figure 5, gas arriving in regional regulators is fed into polyethylene pipes, which carry the gas to the service boxes on

[14] See http://www.dogalgaz.com.tr/

[15] Appendix Table 1 presents the list of provinces with natural gas infrastructure by 2011 along with the year of adoption and natural gas subscription rates in 2011.

[16] For example, the companies in charge of distribution in the three largest provinces, Istanbul, Ankara, and Izmir are Igdas, Baskentgaz, and Izmirgaz, respectively.

streets and in front of buildings. Both the regional regulators and the service boxes contain security valves to cut off gas flow in the event of an emergency.

There are a number of factors that determine the reasons why certain provinces have adopted natural gas earlier than others and why the rate of penetration has been different across these provinces once they adopt it. First of all, whether a household switches to natural gas for heating and cooking purposes after a province has access to natural gas is largely voluntary. Applications for subscribing to natural gas services are made to the distribution companies either by owners of individual housing units or businesses, or jointly as the residents of a multi-unit building. If there is no natural gas service box on the street of the applicant, then distribution companies install one on their schedule. In buildings with central heating systems using another type of fuel, a majority decision among the individual residents is required in order to change the system to either individual or central heating with natural gas. Similarly, in buildings using individual heating systems with another type of fuel, the residents, who want to preserve the individual system but want to switch to natural gas, need to take a majority decision. There is a one-time subscriber connection fee that covers the cost of connecting the internal system with the distribution network within the buildings, including the gas meters. The fee is determined in accordance with the natural gas market regulations and cannot exceed 315 Turkish Liras or about 177 U.S. dollars.

In terms of the variation in the timing of province level adoption, the factors associated with demand, such as the number of housing units (or the population size) and the climate, appear to play an important role (Aras and Aras, 2005). This is not surprising because, as mentioned previously, the companies responsible for establishing and running the natural infrastructure in provinces are privately owned. Thus, it is not surprising that highly populated provinces like Istanbul, Ankara, and Bursa are among the early adopters. However, there are also exceptions like Izmir, which, despite being the third largest province in terms of population, was introduced to natural gas in 2007, possibly due to its relatively warmer climate and longer distance to main pipeline. Furthermore, the investment in infrastructure required to expand natural gas lines to individual provinces is very costly and often takes many years to recover. Thus, simultaneous and widespread adoption is not feasible. Under such a constraint, the conditions of the terrain and geographic proximity to main natural gas ports built and operated by the state-owned BOTAS also appear to be important factors determining the order by which provinces adopt natural gas. For example, many of the remaining provinces without a natural gas infrastructure are in the far eastern and southern regions of Turkey, areas that are both mountainous and distant from the main ports.

To understand the importance of selection on observables, we run regression models for the binary outcome indicating whether a province has natural gas on a number of province-level characteristics along with year and province level fixed effects. As shown in Appendix Table 2A, there are few observable differences between provinces with access to a natural gas network and those without access to one. However, columns (2) to (4) indicate that controlling for province fixed effects, along with province specific linear and quadratic trends, does a good job of causing these differences to disappear. The p-value from an F-test for joint significance of all the control variables is 0.44 in column (3), which controls for province specific linear trends. The only statistically significant individual coefficient in this model is of the log of motor vehicle ownership per capita. In columns (4) and (5), where we add quadratic trends and region by year specific fixed effects, none of the observables are statistically significant either individually or jointly. In Appendix Table 2B, we present estimates from similar regressions except that the outcome variable is a binary indicator of the presence of a natural gas infrastructure rather than a continuous measure defined as the number of subscribers to natural gas services per capita. Again, none of the observable characteristics considered in this analysis are statistically significant individually or jointly once we account for province specific quadratic trends in column (4). We have also run regressions of the binary indicator of natural gas infrastructure and the rate of natural gas subscribers on each of the control variables. These results are shown in Appendix Tables 4A and 4B. While many of the control variables are significantly associated with the presence of a natural gas infrastructure or the natural gas subscription rate in column (1), these differences become insignificant once we add province fixed effects along with province specific linear and quadratic trends and region by year fixed effects through columns (2) and (5).[17]

Infant Mortality Rate in Turkey

It is well known that in many developing countries, official statistics on deaths, especially, among infants, are incomplete (e.g., Greenstone and Hanna, 2011; Gruber et al., 2012; Victora and Barros, 2001; Anthopolos and Becker, 2010; Becker et al., 1998; Anderson and Silver, 1986). There are usually wide differences in the infant mortality rates reported by the national statistical offices of individual countries and those released by international agencies such as the WHO. Note that the under-reporting is mostly one-sided, i.e., there are far more unreported infant deaths than unreported live births that survive the first year in life (Anthopolos

[17] Note that our identification strategy does not require the levels in infant mortality rates between provinces with and without natural gas to be equal prior to adoption of natural gas. Rather, it assumes that, in the absence of natural gas adoption, the rates of infant mortality could have trended similarly between the two types of provinces. Nevertheless, we allow these trends to be different by accounting for province specific linear and quadratic time trends. Therefore, conditional on the time-variant characteristics, fixed effects, provincial time trends, we are assessing whether provinces with a more rapid penetration of natural gas also experienced a more rapid decrease in infant mortality than other provinces.

and Becker, 2010). The statistics compiled by these international agencies usually adjust for under-reporting by combining information from various demographic surveys, census data, the official vital statistics registries, and by using modeling assumptions in an attempt to reduce the impact of under-reporting (Gruber et al., 2012; Lopez et al., 2001). The underreporting in the official statistics is driven by a number of factors. For example, many deaths, especially those that occur outside of a hospital where risks are higher, go unrecorded (Gruber et al., 2012; Tangcharoensathien et al., 2006; Anthopolos and Becker, 2010). Underreporting is particularly widespread for home deliveries and when the newborn dies only a very short period after birth. In fact, it is not uncommon for midwives to announce deaths as stillbirth rather than a live birth followed shortly by death, in an effort to show respect to a grieving family (Anthopolos and Becker, 2010). In countries like Turkey, in accordance with the Islamic tradition, the dead are usually buried shortly (typically before sundown or within hours) after death, which might also exasperate the under-registering of infant deaths.

We obtained province-level infant mortality data from the Turkish Statistical Institute (TUIK) between years 2001 and 2008 and Turkish Census Bureau for the 2009 and 2011.[18] Our analysis sample consists of 877 province year observations between 2001 and 2011.[19] As shown in Table 1, the average infant mortality rate across all provinces and over the period of 2001 and 2011 is 9.27. However, the average infant mortality rate is higher among province-year observations with natural gas than among without natural gas. Similarly, there is a sharp difference in infant mortality rate between provinces which were introduced to natural gas and those which never had access to natural gas during our sample period.

[18] The mortality records at the province level between 2009 and 2011 were not available from the TUIK at the time this research was conducted. However, we were able to obtain data for these three years from the Turkish Census Bureau. The data from the two sources are largely consistent. Moreover, year fixed effects would account for differences in the data collection procedures between the two agencies if such differences exist.

[19] Fourteen observations with missing information on infant mortality are dropped from the analysis.

As it is the case in many other developing countries, there appears to be an issue with the under-reporting of infant deaths in Turkey. To illustrate this issue, we present the average annual mortality rates for Turkey from three different sources in Appendix Table 3. The first two columns report the average mortality rates based on estimates from the WHO and the United Nations. The third column shows the infant mortality rate obtained from the TUIK.[20] Note that province level data on infant mortality do not exist from the WHO and the United Nations. While the national records from the TUIK are lower than those from the two other sources for every year, the trends in the TUIK and the other two series are similar and the pairwise correlations are very high. In fact, the pairwise correlation is 0.97 for both the series between the TUIK and the WHO series and the TUIK and the United Nations series. Furthermore, the measurement error (or under-reporting) in the infant mortality rate data obtained from TUIK is not a source of concern for our analysis as long as it is not correlated with the adoption and the rate of penetration of natural gas by Turkish provinces. As we discuss in greater detail below, even under a scenario where such correlations are plausible, the province-specific linear and quadratic trends in addition to province fixed effects included in our models would capture those correlations.

IV. Empirical Framework

The net effect of the rate of natural gas penetration on infant mortality rate can be summarized by the following empirical model:

[20] For example, Gruber et al. (2012) study the effects of a healthcare reform implemented in Thailand on a health care utilization and infant mortality. The infant mortality rates that they obtained from the Thailand Ministry of Public Health exhibit large differences from those reported in the World Bank Development Indicator Database. As they report in Table 4, the vital statistics registry estimates are lower than those of the World Bank by a factor of about 2.5. In a recent paper examining the impact of environmental regulations on infant mortality in India, Greenstone and Hanna (2011) report that the city-level infant mortality data that they use are about a third of the rate measured from survey measures of infant mortality rates. In the absence of data on infant mortality from Indonesia, Jayachandran (2009) imputes deaths from “missing children” in the 2000 Census.

$$IMR_{pt} = X_{pt}\,\beta_o + \beta_1 NG_{pt} + \varepsilon_{pt}, \qquad (1)$$

where IMR_{pt} represents the natural logarithm of the infant mortality rate in province p and year t.[21] Our primary measure of natural gas penetration, NG_{pt}, is the number of natural gas service subscribers per 100 persons. The number of subscribers is the total number of household and business units with access to natural gas. We also present results from a binary treatment model, where the treatment is defined as whether or not the province has a natural gas infrastructure.[22] X_{pt} is a set of exogenous determinants of infant mortality described above. The ε_{pt} is the unobserved determinants of infant mortality.

The coefficient of interest in equation (1) is β_1, the impact of the rate of penetration of natural gas on infant mortality rate. However, the causal interpretation of the coefficient β_1 is complicated due to omitted variables that are likely to be correlated with both the availability of natural gas infrastructure and infant mortality. For example, as shown in Table 1, provinces with natural gas infrastructure are more likely to be urban, industrial, and with more motor vehicles per capita. Thus, these provinces may also have higher levels of infant mortality despite having a natural gas infrastructure. In order to control for the effect of these factors, we rely on the longitudinal nature of our data and incorporate a series of fixed effects into equation (1):

[21] It is common to use the log of infant mortality rate as opposed to the level in similar contexts (e.g., Murtin, in press; Ruhm, 2000; Tanaka, 2005; Farahani et al., 2009; Anand and Baernighausen, 2004; Flegg, 1982; Jamison et al., 2004). Those provinces in the treatment category that already have small levels of infant mortality rate may experience only small improvements in their infant mortality rate in response to the adoption of natural gas. This may be in contrast to provinces with high levels of infant mortality rate, which may experience large swings in infant mortality. However, we also estimate our models using the level of infant mortality rate as the outcome and the results from these models are very similar to those presented here and are available from the authors upon request.

[22] We also experiment with the natural logarithm of the number of units with natural gas per 100 persons. Note that the number of subscribers is zero for each province in the treatment group before the treatment starts. Thus, we replace the zeros by one in order to preserve these province*year observations in the analysis. These results are similar to those presented here and are available from the authors upon request.

$$IMR_{pt} = X_{pt}\,\beta_0 + \beta_1 NG_{pt} + \omega_p + \lambda_t + \tau_{pt} + \tau^2_{pt} + \varepsilon_{pt}. \qquad (2)$$

In equation (2), the ω_p is a set of binary indicators for each province, which captures permanent differences across provinces. These differences may be related to factors such as the geographic proximity to a major hospital, hospital quality, culture, status of women, climate, religious tendencies, and ethnic composition, which may be correlated with both infant mortality and a province's transition to natural gas infrastructure. These fixed effects also account for province-specific time-invariant sources of measurement error. The λ_t is a vector of binary indicators for each year, representing any nationwide trends and shocks that may influence infant mortality, such as recessions and changes in environmental laws and regulations nation-wide (e.g., the ban on the use of leaded gasoline in 2004 and the national ban on indoor smoking in public places in 2009).

However, some of the unobserved differences between provinces with and without natural gas may be time-variant. To account for such differences, equation (2) also controls for province-specific linear and quadratic time trends as denoted by τ_{pt} and τ^2_{pt}. Adding these trend variables to the model in addition to controlling for province and year fixed effects also relaxes the parallel trends assumption of the simple difference-in-difference model. Relaxing this assumption is important because it is likely to be violated. For example, it is possible that many provinces that adopted natural gas were experiencing a worsening (or a slower decrease in) infant mortality rate compared to other cities. In fact, this is likely if these provinces were increasingly becoming urban and were experiencing rapid industrialization, a development which might have put pressure on the officials to invest in natural gas infrastructures. Thus, equation (2) accounts for differences across provinces in both levels and trends in the rate of infant mortality, and identifies the effect of natural gas as deviations from those trends. Finally, we further enrich the specification in equation (2) by controlling for region by year fixed effects that would account for any spillovers to neighboring provinces as well as any time-variant differences in unobserved heterogeneity that are common to provinces within a region.[23]

Under-reporting in Infant Mortality Rate

As mentioned above, under-reporting in infant mortality rate is unlikely to cause a problem in our analysis. To illustrate this point more formally, suppose that the true infant mortality rate is $IMR_{pt}*$. Then the observed infant mortality rate can be expressed as

$$IMR_{pt}=IMR_{pt}*-k_{pt},$$

where $IMR_{pt}*=Actual\_Deaths_{pt}/Live\_births_{pt}$; $IMR_{pt}=Reported\_Deaths_{pt}/Live\_births_{pt}$; and $k_{pt}=Unreported\_Deaths_{pt}/Live\_births_{pt}$. Therefore, the error term in equation (2) can be rewritten as $\varepsilon_{pt} = \varphi_{pt} - k_{pt}$, where φ_{pt} is the true error term. As long as the measurement error (or under-reporting), k_{pt}, is uncorrelated with the NG_{pt}, the β_1 will be an unbiased estimate of the impact of natural gas penetration on infant mortality rate. We cannot think of plausible scenarios to suggest such a correlation. One argument could be that there may be a positive correlation between the adoption of natural gas and overall quality in government services in health care. A failure to

[23] The busier economic activity in certain regions like Marmara, which includes major urban and industrial hubs like Istanbul, Bursa, and Kocaeli, may have effects on all the provinces within that region. For example, Bursa and Istanbul are connected to each other through highly congested routes that have to pass through Yalova, a smaller and less urban province within the same region. Therefore, any air pollution, for example caused by the traffic congestion between Bursa and Istanbul, may also contaminate the air in Yalova. Controlling for region by year fixed effects would mitigate concerns about the aggregate effects of these factors.

account for such heterogeneity would cause the estimate of β_1 to be biased upward. However, if the improved quality of care in hospitals results in an increased proportion of births delivered in hospitals rather than homes, then the extent of under-reporting in the infant mortality should go down. In essence, under-reporting should be near zero if all births are delivered at hospitals. In that case, our estimate of β_1 would be biased downward. Note that, in all of our regressions, we control for the number of hospitals, hospital beds, and physicians per capita at the province level as well as an indicator for whether the province has adopted the Family Physician Program. Also the provinces that switch to natural gas are typically more urban and higher income than others. It is likely that a smaller proportion of births are delivered at homes than hospitals in these provinces relative to low-income rural provinces. This would suggest that underreporting tends to be larger in poor and less urban provinces (Anthopolos and Becker, 2010), but these are also the provinces less likely to have access to a natural gas infracturture. One may also argue that the improvement in the quality of health care services itself may account for some of the reduction in infant mortality rate. Note that we further guard against any bias from such omitted factors that may be correlated with both infant mortality and the adoption and expansion of natural gas services across provinces by controlling for province fixed effects and province specific linear and quadratic time trends in all of our models. In addition, we include region by year fixed effects in our richest specification. If anything, our estimate of the impact of natural gas subscription rate on infant mortality rate gets only slightly larger when province specific trends and region by year fixed effects are accounted for. Similarly, it may also be argued that natural gas penetration could lead to increased awareness among the public, pregnant women in particular, of the harmful effects of air pollution and thus, reduce their exposure to air pollution by engaging in avoidance behavior. Although the reduction in infant mortality can still be attributed to the treatment, the mechanisms would be different. In any case, province specific linear and quadratic trends along with region by year fixed effects would also control for these unobservables.

Instrumental Variables

The estimates from equation (2) would yield the reduced form impact of natural gas adoption on infant mortality rate. These estimates are novel and interesting in their own right. Next, we supplement our empirical framework with structural equations using data on the measures of two types of air pollutants, including particulate matter (PM_{10}) and sulfur dioxide (SO_2). We obtained these measures from the Turkish Ministry of Health.[24] Note that we have these measures only for the sub-period of 2002-2010 for an unbalanced panel. In particular, we have 490 and 485 year and province observations on particulate matter and sulfur dioxide, respectively.[25] The descriptive statistics in Table 1 indicate that the average levels of particulate matter and sulfur dioxide are lower in provinces that have accessed to a natural gas infrastructure at some point during our analysis period, although the difference is statistically significant only for the particulate matter. However, the average particulate matter is higher in province-year observations with a natural gas infrastructure than those without a natural gas infrastructure, while the opposite is the case for sulfur dioxide.

Note that an appropriate causal model for the impact of air pollution on infant mortality rate can be expressed as follows:

$$IMR_{pt} = X_{pt}\, \mu_0 + \mu_1\, P_{pt} + \omega_p + \lambda_p + \varsigma_{pt}, \qquad (3)$$

[24] Air pollution measures are the averages computed at the province centers. In calculating annual averages, measurements are taken for a minimum of 21 days for each month for at least nine months.
[25] Most of the missing observations on pollution variables come from the period prior to 2007.

where P_{pt} is natural logarithm of one of the two air pollutant measures. In this model, the μ_1 is interpreted as the impact of air pollution on infant mortality rate. Note that equation (3) accounts for permanent differences across provinces and nationwide trends through province-fixed effects and year fixed effects, respectively.

Next, suppose the relationship between air pollution and natural gas penetration rate is determined by the following first-stage equation:

$$P_{pt} = X_{pt}\,\pi_0 + \pi_1\,NG_{pt} + \omega_p + \lambda_p + \upsilon_{pt}. \qquad (4)$$

Equations (3) and (4) imply the reduced form relationship between the natural gas penetration and infant mortality rate expressed in equation (2). Then the reduced form effect of natural gas penetration on infant mortality rate is $\beta_1 = \mu_1{*}\,\pi_1$. The causal effect of air pollution on infant mortality rate is then estimated using an instrumental variables method. The idea underlying this approach is that the variation in NG_{pt} is exogenous once we account for fixed effects. Note that another advantage of the instrumental variables strategy in this context is that it would likely minimize bias from classical measurement error in air pollution.

V. Results

Table 2 presents results from the estimation of equation (2). Each cell in the table represents the estimate on the number of subscribers to natural gas services per 100 persons and its standard error. Standard errors are robust to any form of heteroscedasticity and clustered at the province level to allow for correlation at a given time and across time within provinces

(Bertrand et al., 2004).[26] Column (1) shows the estimates for natural gas services subscription rate without any control variables. Columns (2) and (3) add year fixed effects and a full set of time-variant province characteristics, respectively, and column (4) controls for permanent differences across provinces through province fixed effects. In columns (5) and (6), we present versions of equation (2) with province-specific linear and quadratic time trends, respectively. Finally, in column (7), we show results from a fully saturated model, which also incorporates region by year fixed effects in an attempt to control for any region specific time varying factors associated with natural gas expansion and infant mortality. This specification could also account for any spillovers to the surrounding provinces that are associated with natural gas adoption as well as any differences in region level government policies, such as healthcare interventions.[27]

As shown in Table 2, the estimates for the natural gas subscription rate exhibit substantial variation across various specifications. The estimate on the NG_{pt} in the most basic model presented in column (1) is 0.033, suggesting that a one-percentage point increase in the natural gas subscription rate per 100 persons is associated with a 3.3 percent increase in infant mortality rate. The positive sign on the estimate confirms our earlier arguments about the endogeneity of natural gas infrastructure, i.e., provinces that gain access to a natural gas infrastructure are different from other provinces in ways that are correlated with infant mortality. As mentioned previously, these provinces are more likely to be urban and industrial than others. Since urbanization and industrialization are likely to be positively correlated with infant mortality,

[26] We also estimated weighted regressions using the population density as a weight. These estimations did not cause any appreciable changes to the results presented here. The results from the weighted regressions are available from the authors upon request.

[27] There are various levels of regional classifications in Turkey defined by TUIK. These regions are based on clusters of adjacent provinces and are merely for geographic and statistical purposes. Here we use the 12 region classification, which includes the northeast Anatolia, eastern Anatolia, central Anatolia, southeastern Anatolia, Istanbul, western Marmara, Mediterranean, eastern Marmara, western Anatolia, Aegean, western Black Sea, and eastern Black Sea regions. We also estimated this specification using the 26 sub-region classification. Despite the reduction in the number of degrees of freedom, these results are similar to those presented here quantitatively and in terms of statistical significance.

failing to control for these differences would cause the estimate on natural gas subscription rate to be biased downward, and like in our case, possibly switch sign. We see that the estimate remains almost identical when we control for year fixed effects in column (2). As shown in column (3), controlling for a set of time-variant differences across provinces causes the estimate to decrease by half. The estimate in column (3) indicates that a percentage-point increase in natural gas subscription rate is associated with a 1.7 percent increase in infant mortality. The large reduction in the size of the estimate is again indicative of the endogeneity of natural gas adoption and points to the importance of fully accounting for the underlying differences across provinces. The results from the first important step toward accounting for this endogeneity are revealed in column (4), where we control for province fixed effects. Consistent with our predictions, doing so not only makes a dramatic difference in the size of the estimate, but also causes its sign to switch to negative. According to the point estimate, a one-percentage point increase in the penetration rate of natural gas lowers the infant mortality rate by 2.5 percent. And the estimate is statistically significant at the one percent level. In the following two columns, we present results from the full specification in equation (2), which controls for province-specific linear and quadratic trends, respectively. Allowing for differential trends in the infant mortality rate across provinces causes the estimate on the impact of natural gas subscription rate to rise, suggesting that some provinces that adopt a natural gas infrastructure might have an increasing (or decreasing at a slower pace) trend in infant mortality rate in comparison to other provinces. According to the point estimate in column (6), a one-percentage point increase in the subscription rate to natural gas services causes the infant mortality rate to decrease by 4.1 percent.

Finally, in column (7) we present the estimate from a specification that controls for region by year fixed effects along with all the other variables included in the previous columns. Controlling for region by year fixed effects is likely to help mitigate the impact of positive spillovers on air quality enjoyed by provinces without natural gas that are surrounded by provinces in the treatment group. If the rate of infant mortality is reduced in control provinces because of the cleaner air in adjacent provinces that are in the treatment group, this may cause our estimate to be a lower bound. As it turns out, controlling for region by year fixed effects leaves the estimated coefficient on natural gas subscription rate largely unaltered. In particular, the coefficient estimate presented in column (7) indicates that the effect of natural gas penetration rate on infant mortality rate is 4.0 percent.

To put these estimates into context, we next present some simulation results. For instance, as shown in Table 1, the average natural gas subscription rate is 7.9 per 100 persons in province-year observations with natural gas infrastructure. In 2011, there were 8.714 infant deaths for 1,087,933 births in the provinces with a natural gas infrastructure, yielding an infant mortality rate of about 8 per 1,000 births. Holding the number of births, this would suggest that there could be approximately 348 fewer infant deaths in these provinces in 2011 in response to a one-percentage point increase in the natural gas subscription rate. The subscription rate to natural gas services stands at about 11 units per 100 persons in 2011. Then, doubling the capacity of the natural gas services can save about 3,828 lives in one year.

Robustness and Sensitivity Analyses

The results presented above could be driven by either a decrease in the numerator (number of children who die in their first year) or an increase in the denominator (the number of live births). For example, the results could be driven by an increase in the denominator if the natural gas adoption is associated with an increase in the overall quality of health care services. As explained previously, this is unlikely since we control for the number of hospitals and hospital beds per capita along with the number of physicians per capita and an indicator for whether the province implements a family physician program. Furthermore, province level linear and quadratic trends should also help gauge these effects. Another possibility is that the improvements in air quality may lead to a reduction in the number of stillbirths and miscarriages, which would result in an increase in the number of live births. We test this by estimating our models with the logarithm of infant deaths as the dependent variable and the logarithm of births as an additional control variable (Arceo-Gomez, Hanna, and Oliva, 2012). As presented in Panel A of Table 3, performing this test yields estimates that are almost identical with those in Table 2 when province fixed effects, province specific linear and quadratic time trends and region-by-year fixed-effects are specified. For example, the column (7) specification suggests that a one-percentage point increase in the subscription rate to natural gas services causes infant deaths to decrease by 4.0 percent. Therefore, it is unlikely that our results are driven by an increase in births. Next, we estimate models using logarithm of births as an outcome. As shown in Panel B of Table 3, the estimates in specifications from columns (4) to (7) are all very small and statistically insignificant, suggesting that natural gas adoption does not have an effect on the number of babies born.

Note that we use data from all 81 provinces in our analysis. Among these provinces, 20 of them have never accessed to a natural gas infrastructure during our analysis period. To test for the possibility that there is something fundamentally different about these provinces that may be affecting our results, we estimate our models excluding these provinces from the analysis.

Results from the estimation of these models are presented in Table 4. The pattern obtained in Table 4 is very similar to the one in Table 2. Specifically, the estimates in our richest specifications shown in columns (6) and (7) are -0.039 and -0.041, which are almost identical to those presented in Table 2. Therefore, we can rule out the possibility that our results are driven by provinces without a natural gas infrastructure.

Next we explore whether our results are driven by any of the provinces acting as an outlier. One particular candidate is Istanbul which, with its 13.5 million citizens, accounts for over 18 percent of Turkey's total population. It is also one of the largest urban and busiest agglomerations in the world and responsible for over a quarter of Turkey's GDP. Concurrent with the expansion of natural gas infrastructure, Istanbul has experienced a rapid transformation in a multitude of dimensions during the period of our analysis. For example, it saw a surge in the number of private hospitals, which doubled in numbers between 2000 and 2005. Although we control for a number of variables related to the capacity and quality of health delivery services in our models, it may be argued that there remain other related factors that might have coincided with the expansion of natural gas services. One particular candidate is the mass-transit underground railway network, which entered service in 2000 and has caused a major relief in traffic congestion. Then the question is whether and to what extent the control variables and various fixed effects in our models account for these developments in a potential outlier like Istanbul. We test this by estimating the models in Table 2 with Istanbul excluded from the analysis. As shown in Table 5, the results remain almost identical to those in Table 2 when we perform this exercise.[28]

[28] We also estimated our models excluding each of the three other large provinces, Ankara, Izmir, Bursa as well as early adopters like Kocaeli and Eskisehir. Although they are smaller in population and economic activity, some of these provinces have elements that resemble Istanbul in certain respects. Again, our results are extremely robust to the exclusion of these provinces from the analysis. These results are available from the authors upon request.

Our analysis investigates whether an increase in the intensity of treatment, i.e., number of subscriptions to natural gas services per capita, is associated with a lower infant mortality rate. This allows us to examine the effect of the entire function of average treatment effects over all possible values of the treatment intensities. In contrast, most of the relevant literature on the program evaluation deals with the estimation of causal effects of a binary treatment. Since a binary treatment approach pools all treatment provinces together in one treatment group, the results cannot rule out the possibility that the effects are driven not by provinces that were most treated by natural gas adoption, but by ones that were less treated (Adorno et al., 2007; Chakrabarti, 2008). This issue may be particularly important in our case where the intensity of treatment exposure changes considerably across provinces. In an attempt to assess the sensitivity of our results to imposing the treatment intensity to be identical across provinces, we estimate conventional difference-in-difference models using a binary treatment variable defined by the timing of adoption of a natural gas infrastructure. Results from these models, as shown in Table 6, follow a pattern similar to those in Table 2. In particular, the specifications in the first three columns produce estimates with a positive sign, clearly pointing to the endogeneity of the adoption of natural gas. But, the specification in column (4), which controls for time and province fixed effects along with a full set of control variables, indicates that adoption of natural gas is associated with a 18.9 percent decrease in infant mortality rate. However, incorporating province-specific linear and quadratic trends in columns (5) and (6) as well as region by year fixed effects in column (7) makes the estimate no longer statistically significant at conventional levels. As indicated by this exercise, failing to recognize the continuous nature of the treatment in this case may lead to a misleading conclusion about the impact of natural gas on infant mortality.

Instrumental Variables

To explore the potential channel between IMR and natural gas rate, we next employ models using two-stage least squares (2SLS) in which province level air pollution measures are instrumented on natural gas subscription rate. Panel A of Table 7 presents evidence on the first stage relationship between pollution measures - particular matter and sulfur dioxide - and natural gas subscription rate. The results from the first stage lend strong support to the hypothesis that the effects presented above are driven by the improvements in air quality caused by the deployment of natural gas networks. In particular, the point estimates suggest that a one-percentage point increase in the natural gas services subscription rate is associated with a 2.1 percent decrease in level of particulate matter and a 4.3 percent decrease in the level of sulfur dioxide. Note that the sample size in these models is smaller due to lack of complete data on air pollution. Despite the smaller sample size, both estimates are statistically significant at conventional levels.

The instrumental variables estimates of the causal impact of air pollution on infant mortality rate are presented in Panel B of Table 7. As shown in the table, air pollution has a positive and statistically significant impact on infant mortality. The elasticity estimates are 1.25 and 0.63 for particulate matter and sulfur dioxide. We are also able to compare our elasticity estimates to those obtained in several previous studies. For example, our estimates are particularly consistent with those of Tanaka (2012) who report elasticities of 0.95 for particulate matter and 0.82 for sulfur dioxide in a study of the impact of air pollution on infant mortality in China. Focusing on the estimates derived from the United State context, the elasticity estimates for particulate matter documented by Chay and Greenstone (2003a), Currie, Neidell, and

Schmieder (2009), and Currie and Neidell (2005) are 0.285, -0.008, and 0.001, respectively.[29] In a recent study focusing on Mexico, Arceo-Gomez, Hanna, and Oliva (2012) find an elasticity of 0.42 for particulate matter, which is smaller than our estimate, but larger than those reported for the United States. To the extent that our estimates are larger than those reported by studies using data from the United States and consistent with those obtained for China, and to some extent, Mexico, the number of lives of infants saved due to improved air quality is likely to be higher in the developing countries than it is for the developed countries.[30]

VI. Conclusions

Industrialization and economic development have brought with it dramatic improvements in living conditions of vast populations in developing countries through higher incomes and better health care. However, these benefits have come at the substantial cost of deterioration in environmental conditions and air quality, which threatens some of these gains achieved by these countries. Furthermore, there are very few viable policy options or enforcement mechanisms available to rich countries that could induce developing countries to take meaningful steps toward addressing environmental problems. One policy instrument commonly used to control air pollution is regulations. However, there are serious challenges to implementing regulations successfully, especially in developing countries, due to weak governance and corruption problems. Furthermore, concerns over global climate change are often sidelined in these countries due to a strong desire to maintain robust economic growth. Therefore, international efforts to reduce carbon emissions face major challenges as many in the developing world object to significant cuts voluntarily. Under these circumstances, natural gas has become a popular

[29] These figures are obtained from Table 8 in Arceo-Gomes, Hanna, and Oliva (2012).
[30] One exception is Knittel, Miller, and Sanders (2011) who find an effect corresponding to an elasticity of 1.88 studying the impact of air pollution on infant mortality in California.

source of fuel and one that could help efforts to limit carbon emissions globally without causing interruptions in the mounting energy needs of these countries in the short run.

In this paper, we consider the impact of the expansion of natural gas services for residential and commercial use on the rate of infant mortality in Turkey. In identifying this impact, we use the variation in the timing and intensity in the deployment of natural gas infrastructures across Turkish provinces between 2001 and 2011. Our results indicate that the expansion of natural gas services leads to a significant reduction in the rate of infant mortality. The estimate from our most comprehensive model suggests that a one-percentage point increase in the rate of subscriptions to gas services would cause the infant mortality rate to decrease by 4 percent.

Using supplemental data on total particulate matter and sulfur dioxide available for a sub-period of our analysis sample, we also produce direct estimates of the impact of improved air quality associated with the adoption of natural gas on infant mortality. Our elasticity estimates from this instrumental variables analysis are 1.25 and 0.63 for particulate matter and sulfur dioxide, respectively. A comparison of these estimates with those reported from other developing countries and the United States indicates that potential benefits associated with reducing air pollution may be greater in the developing countries than the developed countries. This finding is consistent with the explanations that improvements in air quality are more beneficial at higher baseline levels of air pollution or these benefits are greater in environments where infants are already weakened by other factors, such as poor access to health care, weak sanitary conditions, or more widespread diseases (Arceo-Gomez, Hanna, and Oliva, 2012; Tanaka, 2012).

Note that replacement of coal by natural gas can result in lower infant mortality through two channels. As demonstrated by our instrumental variables analysis, there are significant external benefits of improved air quality associated with the use of natural gas, as opposed to other fossil fuels such as coal. But it is also likely that there are significant private benefits enjoyed by the subscribers of natural gas services since they would be exposed to lower levels of indoor air pollution. Understanding the extent to which these benefits are split between the two channels is beyond the purpose of this paper, but is important in order to design socially optimal policies to tax and regulate natural gas.

References

350 Ankara. (2010). Kuresel Isinma, Iklim Degisikligi Meselesi, Hepimizin Meselesi. Press Release. http://350ankara.blogspot.com/2012/11/350-ankara-basn-acklamas.html#!/2012/11/350-ankara-basn-acklamas.html.

Adorno, V., Bernini, C., & Pellegrini, G. (2007). The impact of capital subsidies: new estimations under continuous treatment. *Giornale degli economisti e annali di economia, 66*(1), 67.

Anand, S., & Baernighausen, T. (2004). Human resources and health outcomes: cross-country econometric study. *Lancet, 364*, 1603-1609.

Anderson, B. A., & Silver, B. D. (1986). Infant mortality in the Soviet Union: Regional differences and measurement issues. *Population and Development Review, 12*(4), 705-738.

Anthopolos, R., & Becker, C. M. (2010). Global Infant Mortality: Correcting for Undercounting. *World Development, 38*(4), 467-481.

Aras, H. & Aras, N. (2005). Eskişehir'de konutsal doğal gaz talebine ekonomik göstergelerin ve dış ortam sıcaklığının etkileri. *Mühendis ve Makine Dergisi*, 46(540), 20-27.

Arceo-Gomez, E. O., Hanna, R., & Oliva, P. (2012). Does the Effect of Pollution on Infant Mortality Differ Between Developing and Developed Countries? Evidence from Mexico City. NBER Working Paper No.18349.

Becker, C. M., Bibosunova, D., Holmes, G., & Ibragimova, M. (1998). Maternal care vs. economic wealth and the health of newborns: Bishkek, Kyrgyz Republic and Kansas City, USA. *World Development, 26*(11), 2057-2072.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How Much Should We Trust Differences-In-Differences Estimates? *The Quarterly Journal of Economics, 119*(1), 249-275.

BOTAS. (2010). *2010 Faaliyet Raporu*. Retrieved from http://www.botas.gov.tr/icerik/docs/faalrapor/2010/tur/fr2010_full.pdf.

Boxall, P. C., Chan, W. H., & McMillan, M. L. (2005). The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis. *Resource and Energy Economics, 27*(3), 248-269.

Chakrabarti, R. (2008). Can increasing private school participation and monetary loss in a voucher program affect public school performance? Evidence from Milwaukee. *Journal of Public Economics* vol. 92, issues5-6, pp. 1371-1393.

Chay, K., and Greenstone, M. (2003a). The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession. *Quarterly Journal of Economics*, 118(2003), 1121-1167.

Chay, K., and Greenstone, M. (2003b). Air quality, infant mortality, and the Clean Air Act of 1970. NBER Working Paper No. 10053.

Choi, H., Jedrychowski, W., Spengler, J., Camann, D. E., Whyatt, R. M., Rauh, V., Perera, F. P. (2006). International studies of prenatal exposure to polycyclic aromatic hydrocarbons and fetal growth. *Environmental health perspectives, 114*(11), 1744.

Currie, J., Greenstone, M., & Moretti, E. (2011). Superfund Cleanups and Infant Health. *American Economic Review, 101*(3), 435-441.

Currie, J., & Neidell, M. (2005). Air Pollution and Infant Health: What Can We Learn from California's Recent Experience? *The Quarterly Journal of Economics, 120*(3), 1003-1030.

Currie, J., Neidell, M., & Schmieder, J. F. (2009). Air pollution and infant health: Lessons from New Jersey. *Journal of Health Economics, 28*(3), 688-703.

Currie, J., & Vogl, T. (2012). Early-Life Health and Adult Circumstance in Developing Countries. NBER Working Paper No. 18371.

Currie, J., & Walker, R. (2011). Traffic Congestion and Infant Health: Evidence from EZPass. *American Economic Journals-Applied Economics, 3*(1).

Dejmek, J., Solanský, I., Benes, I., Lenícek, J., & Srám, R. J. (2000). The impact of polycyclic aromatic hydrocarbons and fine particles on pregnancy outcome. *Environmental health perspectives, 108*(12), 1159.

DeShazo, P., Ladislaw, S., & Primiani, T. (2007). Natural Gas, Energy Policy, and Regional Development Brazil and the Southern Cone *Policy Papers on the Americas* (Vol. 18): The Center for Strategic and International Studies.

Energy Information Administration. (2011). *Turkey Energy Data, Statistics and Analysis - Oil, Gas, Electricity, Coal.*: Retrieved from http://www.eia.gov/cabs/Turkey/pdf.pdf.

Farahani, M., Subramanian, S., & Canning, D. (2009). The effect of changes in health sector resources on infant mortality in the short-run and the long-run: A longitudinal econometric analysis. *Social Science & Medicine, 68*(11), 1918-1925.

Flegg, A. T. (1982). Inequality of Income, Illiteracy and Medical Care as Determinants of Infant Mortality in Underdeveloped Countries. *Population Studies, 36*, 441-458.

Guide for Understanding Turkey (2010). Turkiye'yi Anlama Kilavuzu. Ipsos KMG. http://www.turkiyeyianlamakilavuzu.com/#

Greenstone, M., & Hanna, R. (2011). Environmental regulations, air and water pollution, and infant mortality in India. NBER Working Paper No.17210.

Gruber, J., Hendren, N., & Townsend, R. (2012). Demand and reimbursement effects of healthcare reform: health care utilization and infant mortality in Thailand. NBER Working Paper No.17739.

Ha, E. H., Hong, Y. C., Lee, B. E., Woo, B. H., Schwartz, J., & Christiani, D. C. (2001). Is air pollution a risk factor for low birth weight in Seoul? *Epidemiology, 12*(6), 643.

International Energy Agency. (2005). Energy Policies of IEA Countries: Turkey 2005 Review. Paris: OECD/IEA.

International Energy Agency. (2009). *Natural Gas Information 2009*. Paris: OECD/IEA

International Energy Agency. (2011). *Natural Gas Information 2011*. Paris: OECD/IEA.

International Energy Agency. (2012). *Natural Gas Information 2012*. Paris: OECD/IEA.

International Energy Agency. (2013). Frequently Asked Questions: Coal. http://www.iea.org/aboutus/faqs/coal/

Jacquet, J. (2011). Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale: Ithaca, NY: Cornell University City and Regional Planning.

Jamison, D., Sandbu, M., & Wang, J. (2004). *Why Has Infant Mortality Decreased at Such Different Rates in Different Countries?* Disease Control Priorities Project.

Jayachandran, S. (2009). Air quality and early-life mortality: evidence from Indonesia's wildfires. *Journal of Human Resources* 44(4): 916-954.

Jiping, Z. (2010). *China's Natural Gas Demand and CNPC's Natural Gas Business Strategy*. http://www.cnpc.com.cn/en/press/speeches/China_s_Natural_Gas_Demand_and_CNPC_s_Natural_Gas_Business_Strategy_.htm?COLLCC=1351754029&.

Kaygusuz, K. (2007). Energy use and air pollution issues in Turkey. *CLEAN–Soil, Air, Water, 35*(6), 539-547.

Knittel, C, Miller, D. L., and Sanders, N.J. (2011). Caution, Drivers! Children Present: Traffic, Pollution, and Infant Health. NBER Working Paper No. 17222.

Li, N., Sioutas, C., Cho, A., Schmitz, D., Misra, C., Sempf, J., and Nel, A. (2003). Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage. *Environmental health perspectives*, *111*(4), 455.

Lopez, A., Ahmad, O., Guillot, M., Inoue, M., Ferguson, B., & Salomon, J. (2001). *Health Systems Performance Assessment Peer Review Technical Documentation. IV Outcomes: Population Health - Life tables for 191 countries for 2000: data, methods, results*. World Health Organization: Evidence and Information for Policy.

Maisonet, M., Correa, A., Misra, D., & Jaakkola, J. J. K. (2004). A review of the literature on the effects of ambient air pollution on fetal growth. *Environmental Research, 95*(1), 106-115.

McMillen, S., & Prakash, N. (2011). *The Economic Impact of Expanding Natural Gas Use in Connecticut*.

Murtin, F. (Forthcoming). Long-term Determinants of the Demographic Transition: 1870-2000. *Review of Economics and Statistics*.

OECD. (2012). *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Retrieved from www.oecd.org/environment/outlookto2050.

Paltsev S.,Jacoby H. D., Reilly J. M., Ejaz Q. J., O'Sullivan F., Morris J., Rausch S., Winchester N., and Kragha O. (2011). The Future of U.S. Natural Gas Production, Use, and Trade. *Energy Policy*, vol. 38, issue 9, pp. 5309-53121.

Perera, F. P., Whyatt, R. M., Jedrychowski, W., Rauh, V., Manchester, D., Santella, R. M., & Ottman, R. (1998). Recent developments in molecular epidemiology: a study of the effects of environmental polycyclic aromatic hydrocarbons on birth outcomes in Poland. *American Journal of Epidemiology, 147*(3), 309-314.

Podesta, J. D., & Wirth, T. E. (2009). Natural Gas—A Bridge Fuel for the 21st Century: Center for American Progress.

Ruhm, C. (2000). Parental leave and child health. *Journal of Health Economics, 19*(6), 931-960.

Shahidehpour, M., Fu, Y., & Wiedman, T. (2005). Impact of natural gas infrastructure on electric power systems. *Proceedings of the IEEE, 93*(5), 1042-1056.

Siddiqui, A. R., Gold, E. B., Yang, X., Lee, K., Brown, K. H., & Bhutta, Z. A. (2008). Prenatal exposure to wood fuel smoke and low birth weight. *Environmental health perspectives, 116*(4), 543.

Tanaka, Sakiko. (2005). Parental Leave and Child Health across OECD Countries. *The Economic Journal, 115*(501), F7-F28.

Tanaka, Shinsuke. (2012). Environmental Regulations on Air Pollution in China and Their Impact on Infant Mortality. Working Paper. Hiroshima University, Graduate School for International Development and Cooperation (IDEC).

Tangcharoensathien, V., Faramnuayphol, P., Teokul, W., Bundhamcharoen, K., & Wibulpholprasert, S. (2006). A critical assessment of mortality statistics in Thailand: potential for improvements. *Bulletin of the World Health Organization, 84*(3), 233-238.

U.S. Energy Information Administration. (2011). *Independent Statistics & Analysis*.

U.S. Environmental Protection Agency. (2012). *Clean Energy: Natural Gas*.

Victora, C. G., & Barros, F. C. (2001). Infant mortality due to perinatal causes in Brazil: trends, regional patterns and possible interventions. *Sao Paolo Medical Journal*, *191*(1), 33-42.

World Health Organization (WHO). (2011). *Air Quality and Health*. Retrieved from http://www.who.int/mediacentre/factsheets/fs313/en/index.html.

Figure 1: Number of Provinces with Natural Gas Infrastructure in Turkey

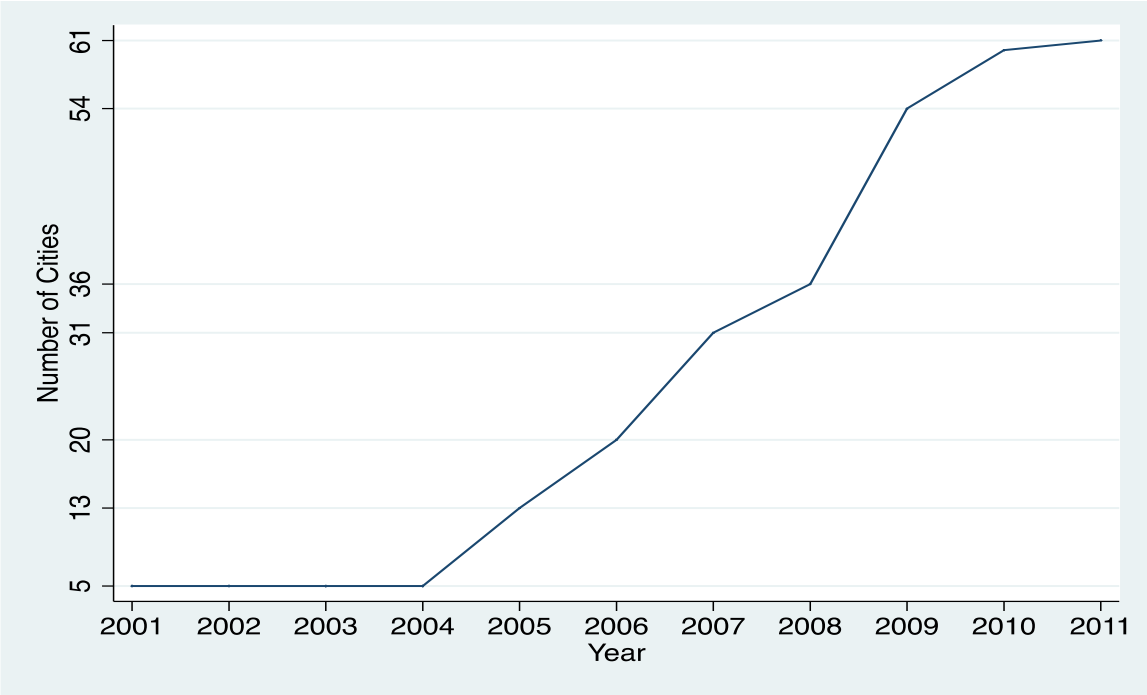
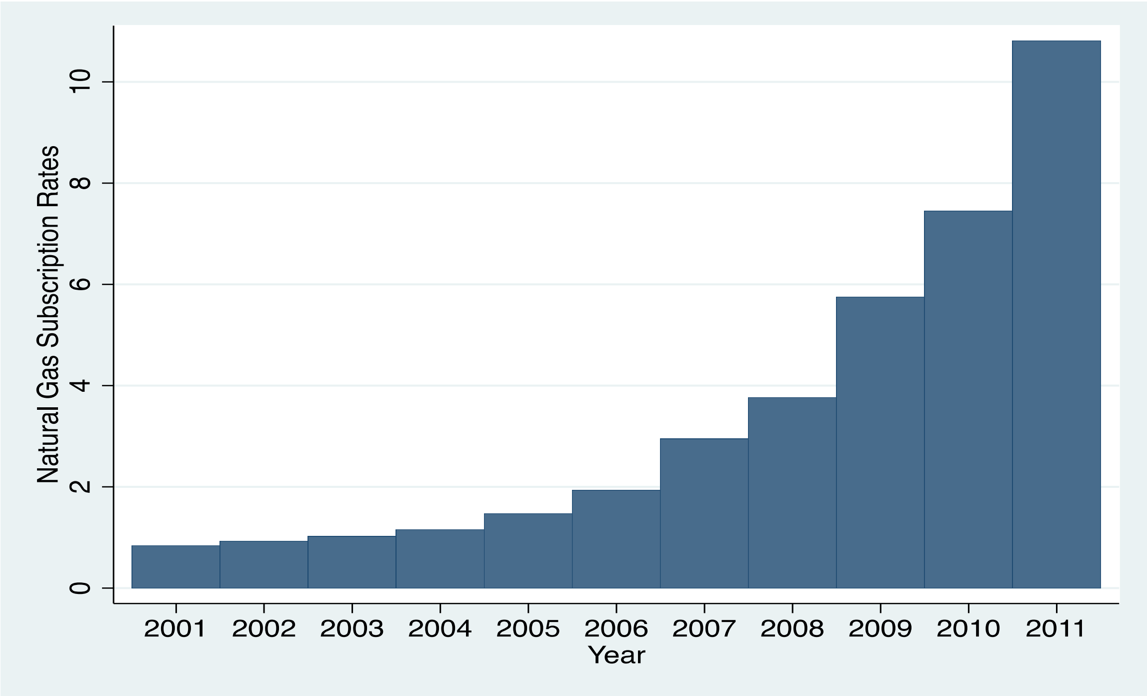
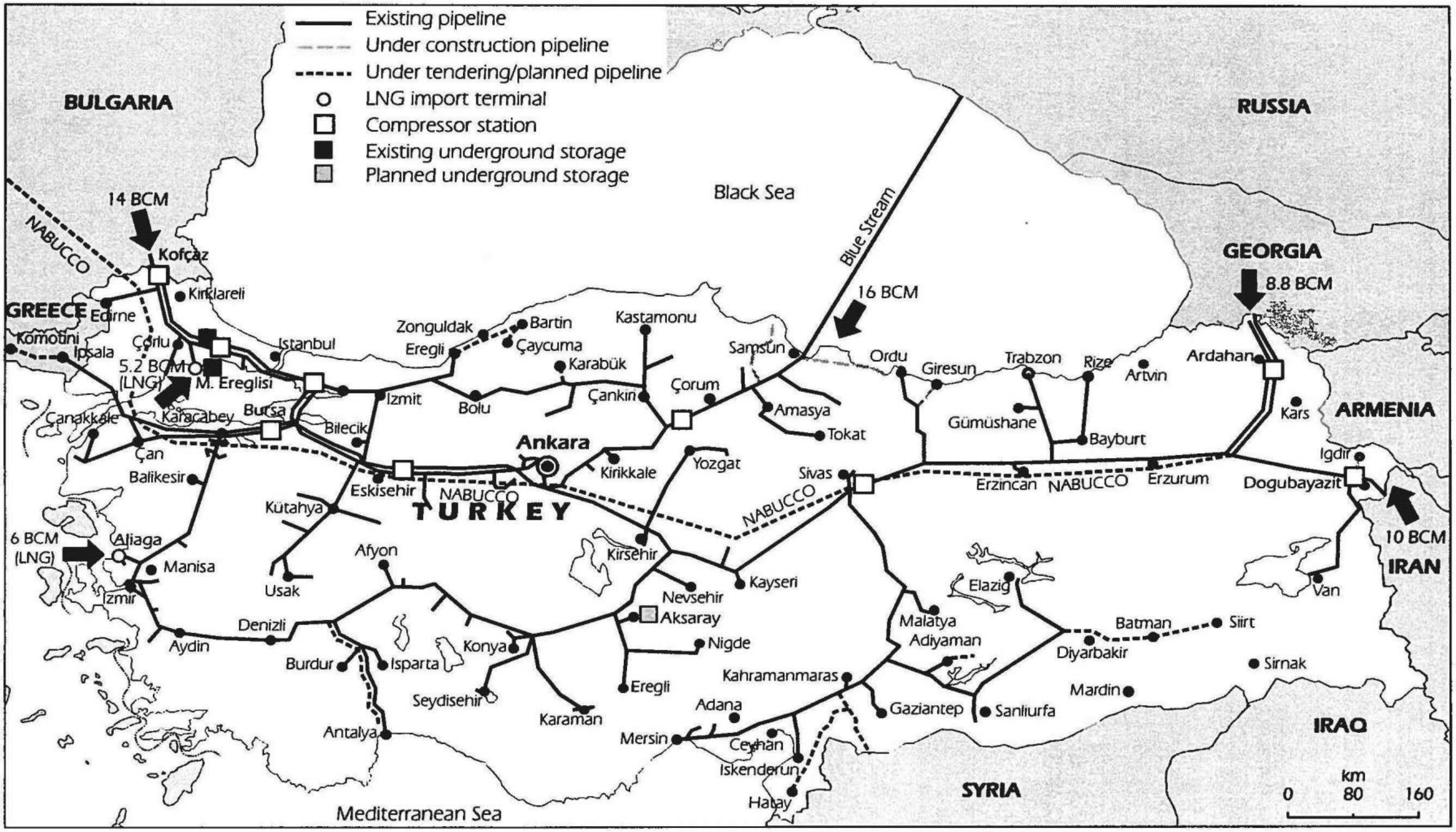


Figure 2: The Number of Subscriptions to Natural Gas Services per 100 persons



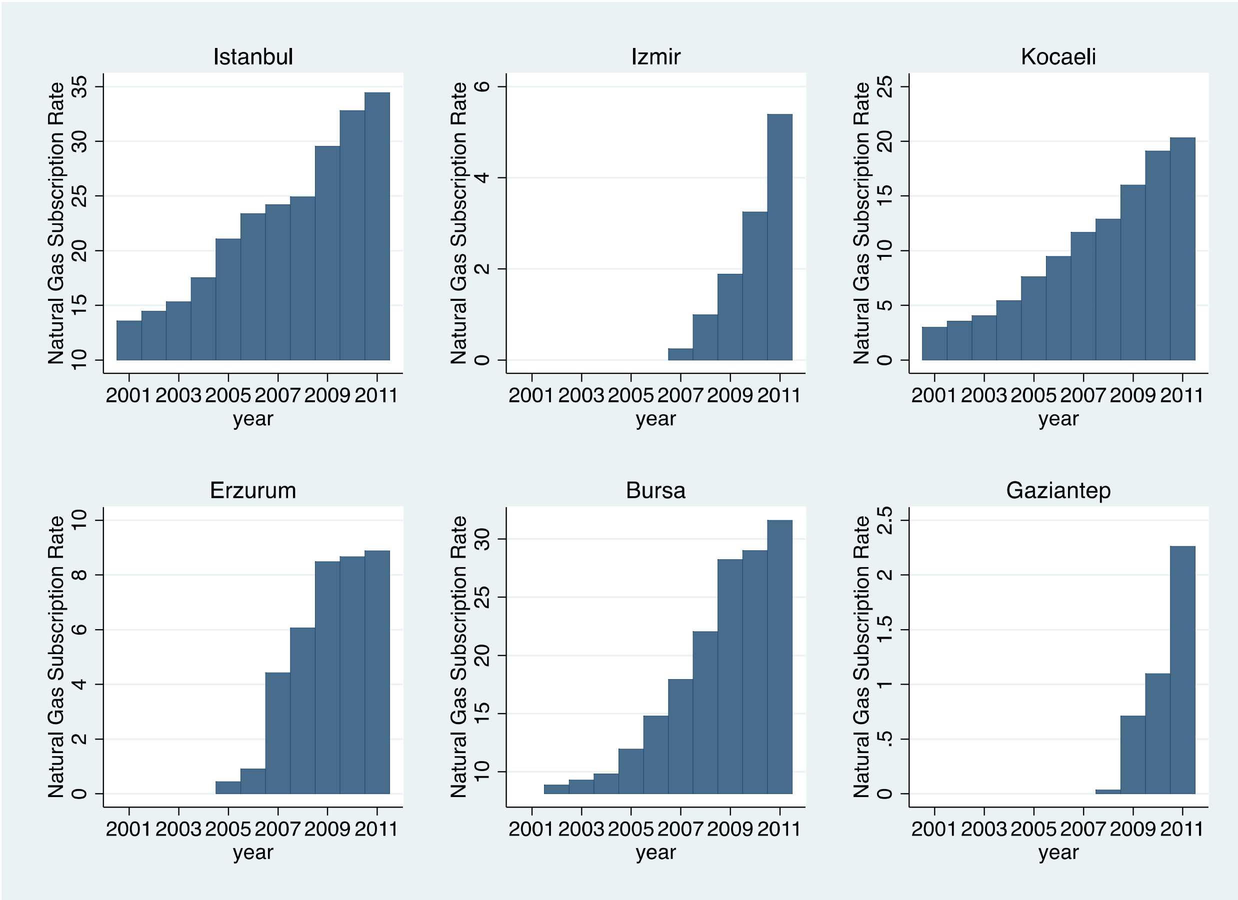
Note: The sample only consists of provinces with access to natural gas services at least one year during the period of 2001-2011. Source: Natural Gas Journal

Figure 3: Map of the Natural Gas Networks in Turkey



The boundaries and names shown and the designation used on maps included in this publication do not imply official endorsement or acceptance by the IEA.
Source: *Natural Gas Information*, IEA/OECD Paris, 2009.

Figure 4: Natural Gas Subscriptions per 100 persons in Select Provinces



Source: Natural Gas Journal.

Figure 5: Natural Gas Flow Chart

Source: Igdas

Table 1: Descriptive Statistics

Variable	(1) ALL	(2) NG=0	(3) NG=1	(4) NG Ever=0	(5) NG Ever=1
Infant Mortality per Thousand Births	9.148	8.003	8.881***	3.138	10.017 ***
	(1.171)	(1.114)	(1.069)	(1.685)	(1.560)
Number of NG Subscriptions in 100K	0.683	---	2.031	---	0.897
	(3.614)		(6.014)		(4.119)
=1 if Natural Gas Subscriptions > 0	0.336	---	---	---	0.442
	(0.473)				(0.497)
NG Rate Per 100 Population	2.648	---	7.871	---	3.476
	(6.142)		(8.435)		(6.831)
Ever Had Natural Gas	0.762	0.641	---	---	---
	(0.426)	(0.480)			
Average Particulate Matter (μg/m^3)	66.194	62.712	70.611***	78.941	63.519***
	(30.611)	(34.188)	(24.739)	(37.151)	(28.388)
Average Sulfur Dioxide (μg/m^3)	39.445	48.220	28.146***	41.048	39.110
	(31.786)	(34.914)	(22.766)	(40.152)	(29.788)
Hospitals Per-100 K Population	2.063	2.052	2.089	2.185	2.025***
	(0.924)	(0.982)	(0.767)	(1.158)	(0.835)
Hospital Beds Per-100 K Population	214.041	196.613	255.971***	159.178	231.214***
	(90.357)	(88.541)	(80.520)	(76.415)	(87.544)
Physicians Per-100 K Population	125.472	107.555	143.210***	94.378	135.426***
	(51.076)	(39.063)	(55.300)	(23.170)	(53.535)
Per-capita Regional GDP	7.770	6.768	10.539***	5.509	8.467***
	(3.458)	(2.835)	(3.524)	(2.399)	(3.439)
Percent High School	16.163	15.489	17.019***	14.296	16.744***
	(3.284)	(3.274)	(3.096)	(3.094)	(3.123)
Percent College	6.676	5.654	7.975***	5.194	7.137***
	(2.570)	(1.987)	(2.643)	(2.121)	(2.525)
Students Per-Teacher	16.913	17.485	15.914***	19.732	16.031***
	(4.379)	(4.929)	(2.949)	(6.099)	(3.212)
Unemployment Rate	10.263	10.315	10.196	10.540	10.177
	(3.762)	(4.232)	(3.067)	(4.383)	(3.547)
Province Has Family Physician Program	0.281	0.134	0.570***	0.234	0.295*
	(0.450)	(0.341)	(0.496)	(0.425)	(0.456)
Motor Vehicles Per capita	161.443	134.716	195.424***	104.133	179.285***
	(78.350)	(79.156)	(62.680)	(87.458)	(65.876)
Governing Party	0.609	0.538	0.749***	0.455	0.657***
	(0.488)	(0.499)	(0.434)	(0.499)	(0.475)
Population	884.199	609.654	1425.845***	366.738	1046.100***
	(1460.947)	(540.491)	(2310.550)	(237.456)	(1635.670)
Observations	877	582	295	209	668

Standard Deviations are in parentheses. *, **, and *** indicate that mean is statistically different between the sample in columns (2) and (3) or columns (4) the 10%, 5%, and 1% levels, respectively.

Table 2: Estimates of Log Infant Mortality on Natural Gas Subscriptions to Population Ratio

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural Gas Rate	0.033***	0.031***	0.017**	-0.025***	-0.036**	-0.041**	-0.040*
	(0.007)	(0.007)	(0.008)	(0.007)	(0.014)	(0.018)	(0.023)
Hospitals Per-100 K			-0.296***	-0.071	-0.005	-0.005	-0.014
			(0.073)	(0.044)	(0.043)	(0.055)	(0.066)
Hospital Beds Per-100 K			0.006***	0.002**	-0.000	-0.000	0.000
			(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Physicians Per-100 K			0.002	-0.000	0.001	0.000	0.000
			(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Percent High School			-0.073**	-0.064***	-0.033	-0.019	0.007
			(0.034)	(0.019)	(0.023)	(0.026)	(0.035)
Percent College			0.002	0.024	0.018	0.028	-0.017
			(0.042)	(0.032)	(0.034)	(0.036)	(0.044)
Log Students Per Teacher			0.342	-0.126	-0.089	-0.068	0.029
			(0.290)	(0.312)	(0.307)	(0.369)	(0.410)
Unemployment Rate			0.067***	0.028***	0.032**	0.005	0.014
			(0.018)	(0.011)	(0.014)	(0.016)	(0.020)
Family Doctor			-0.146	-0.040	0.017	0.012	-0.019
			(0.102)	(0.064)	(0.064)	(0.079)	(0.075)
Log MV Per 1000 People			0.118	-0.385***	0.022	-0.150	0.227
			(0.135)	(0.115)	(0.172)	(0.175)	(0.203)
Governing Party			0.041	-0.042	-0.083	-0.020	-0.003
			(0.086)	(0.070)	(0.072)	(0.071)	(0.079)
Observations	877	877	877	877	877	877	877
R-squared	0.049	0.075	0.373	0.767	0.832	0.867	0.886
Controls For							
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Time Varying Province Characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	No	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	No	No	Yes	Yes
Region-by-year Fixed Effects	No	No	No	No	No	No	Yes

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 3: Estimates of Log Infant Deaths and Log Births

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A							
Dependent Variable: Log Infant Deaths							
Natural Gas Rate	0.014	0.007	0.002	-0.023***	-0.036**	-0.041**	-0.040*
	(0.009)	(0.010)	(0.007)	(0.007)	(0.014)	(0.018)	(0.022)
Log Births	1.419***	1.437***	1.427***	0.432	0.659	0.994	0.660
	(0.059)	(0.058)	(0.058)	(0.338)	(0.600)	(0.795)	(0.913)
Observations	877	877	877	877	877	877	877
R-squared	0.773	0.784	0.842	0.930	0.949	0.960	0.965
Panel B							
Dependent Variable: Log Infant Births							
Natural Gas Rate	0.045**	0.057***	0.035**	0.003	0.000	0.001	0.001
	(0.019)	(0.021)	(0.016)	(0.003)	(0.001)	(0.001)	(0.001)
Observations	877	877	877	877	877	877	877
R-squared	0.077	0.107	0.528	0.995	0.999	0.999	1.000
Controls For							
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Time Varying Province Characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	No	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	No	No	Yes	Yes
Region-by-year Fixed Effects	No	No	No	No	No	No	Yes

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 4: Estimates of Log Infant Mortality on Natural Gas Subscriptions to Population Ratio, Natural Gas Sample

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural Gas Rate	0.020**	0.026***	0.016*	-0.010	-0.020	-0.039**	-0.041*
	(0.008)	(0.008)	(0.008)	(0.009)	(0.014)	(0.019)	(0.024)
Observations	668	668	668	668	668	668	668
R-squared	0.026	0.055	0.370	0.787	0.848	0.880	0.900
Controls For							
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Time Varying Province Characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	No	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	No	No	Yes	Yes
Region-by-year Fixed Effects	No	No	No	No	No	No	Yes

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 5: Estimates of Log Infant Mortality on Natural Gas Subscriptions to Population Ratio, Excluding Istanbul

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural Gas Rate	0.032***	0.030***	0.015*	-0.024***	-0.037**	-0.042**	-0.040*
	(0.008)	(0.009)	(0.008)	(0.007)	(0.014)	(0.019)	(0.023)
Observations	866	866	866	866	866	866	866
R-squared	0.040	0.067	0.366	0.764	0.830	0.865	0.884
Controls For							
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Time Varying Province Characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	No	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	No	No	Yes	Yes
Region-by-year Fixed Effects	No	No	No	No	No	No	Yes

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 6: Estimates of Log Infant Mortality on Binary Natural Gas Indicator

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Binary Natural Gas Indicator	0.539***	0.632***	0.392***	-0.189*	-0.051	-0.066	-0.172
	(0.111)	(0.132)	(0.109)	(0.105)	(0.123)	(0.137)	(0.136)
Observations	877	877	877	877	877	877	877
R-squared	0.069	0.100	0.384	0.765	0.830	0.865	0.885
Controls For							
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Time Varying Province Characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	No	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	No	No	Yes	Yes
Region-by-year Fixed Effects	No	No	No	No	No	No	Yes

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Table 7: Instrumental Variables Estimates of Log Infant Mortality on Air Pollution Measures and the Corresponding First Stage Estimates

Panel A	First Stage Estimates of Log Pollution Measures on Natural Gas Rate	
Natural Gas Rate	-0.021*	-0.043***
	(0.012)	(0.013)
Hospitals Per-100 K	-0.027	-0.089
	(0.126)	(0.142)
Hospital Beds Per-100 K	0.001	0.003**
	(0.001)	(0.001)
Physicians Per-100 K	-0.001	-0.001
	(0.001)	(0.001)
Percent High School	-0.011	-0.030
	(0.031)	(0.028)
Percent College	0.017	0.091**
	(0.035)	(0.045)
Log Students Per Teacher	0.409	-0.327
	(0.407)	(0.772)
Unemployment Rate	-0.008	0.005
	(0.010)	(0.025)
Family Doctor	0.042	0.003
	(0.066)	(0.126)
Log MV Per 1000 People	0.277**	0.222
	(0.122)	(0.201)
Governing Party	0.018	-0.038
	(0.050)	(0.096)
Observations	490	485
R-squared	0.744	0.750

Panel B	IV Estimates of Log Infant Mortality on Log Pollution Measures	
Log Particulate Matter	1.252*	
	(0.748)	
Log Sulfur Dioxide		0.626**
		(0.253)
Observations	490	485
R-squared	0.614	0.683
First Stage F-test	3.432	10.86
First Stage F-test (p-value)	0.068	0.001

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Appendix Table 1: Natural Gas Adoption Year and Natural Gas Subscription Rate in 2011 for Provinces with at Natural Gas Infrastructure

Province	*Adoption Year*	*Subscription Rate in 2011*	*Province*	*Adoption Year*	*Subscription Rate in 2011*
Adana	2010	0.540	Karaman	2009	9.724
Adiyaman	2010	3.851	Kars	2009	1.153
Afyonkarahisar	2008	4.316	Kastamonu	2009	3.783
Aksaray	2006	11.067	Kayseri	2005	23.603
Amasya	2008	13.272	Kirikkale	2007	16.491
Ankara	1988	33.943	Kirklareli	2009	4.160
Antalya	2009	0.046	Kirsehir	2007	16.865
Balikesir	2005	17.334	Kocaeli/Izmit	1996	20.319
Bayburt	2009	10.918	Konya	2005	12.478
Bilecik	2007	26.038	Kutahya	2005	16.309
Bolu	2010	8.229	Malatya	2007	19.067
Burdur	2009	3.686	Manisa	2007	6.914
Bursa	1992	31.613	Mersin	2010	0.512
Canakkale	2007	12.565	Nevsehir	2009	6.696
Cankiri	2009	8.726	Nigde	2007	8.180
Corum	2005	14.606	Ordu	2009	2.515
Denizli	2007	12.404	Osmaniye	2011	0.473
Diyarbakir	2009	4.633	Rize	2009	10.310
Duzce	2006	16.089	Sakarya	2005	14.684
Edirne	2009	4.965	Samsun	2006	8.942
Elazig	2009	12.283	Sanliurfa	2008	3.069
Erzincan	2009	7.396	Sivas	2006	21.868
Erzurum	2005	8.884	Tekirdag	2005	10.523
Eskisehir	1996	38.569	Tokat	2009	3.631
Gaziantep	2008	2.262	Trabzon	2010	0.672
Hatay	2010	0.103	Usak	2006	9.910
Isparta	2009	5.141	Van	2008	1.838
Istanbul	1992	34.446	Yalova	2006	19.130
Izmir	2007	5.390	Yozgat	2007	8.685
Kahramanmaras	2007	4.097	Zonguldak	2006	9.346
Karabuk	2009	9.944			

Notes: Provinces without natural gas infrastructure in 2011 are Sirnak, Mus, Hakkari, Aydin, Ardahan, Mugla, Tunceli, Siirt, Batman, Gumushane, Sinop, Mardin, Kilis, Igdir, Artvin, Bingol, Giresun, Bartin, Bitlis, and Agri. In Ankara, Bursa, Eskisehir, Istanbul, and Kocaeli natural gas infrastructure was developed prior to 2001. Natural gas subscription rate is expressed in per hundred populations.

Appendix Table 2A: Estimates of Binary Indicator of Natural Gas

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per-100 K	-0.077***	0.014	-0.012	-0.006	-0.015
	(0.028)	(0.032)	(0.025)	(0.028)	(0.031)
Hospital Beds Per-100 K	0.001	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Physicians Per-100 K	0.001	0.001	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log Per Capita Regional GDP	0.060	-0.110	0.129	0.018	-0.390
	(0.139)	(0.124)	(0.131)	(0.132)	(0.303)
Percent High School	0.029**	0.025*	0.011	0.017	0.010
	(0.014)	(0.015)	(0.015)	(0.014)	(0.020)
Percent College	-0.012	-0.034	-0.010	0.004	-0.001
	(0.018)	(0.028)	(0.019)	(0.019)	(0.026)
Log Students Per Teacher	0.209	0.162	0.148	0.091	0.045
	(0.141)	(0.116)	(0.108)	(0.132)	(0.153)
Unemployment Rate	-0.014*	-0.014**	-0.005	-0.004	0.007
	(0.007)	(0.006)	(0.006)	(0.005)	(0.011)
Family Doctor	-0.065	-0.010	-0.055	-0.031	-0.032
	(0.074)	(0.066)	(0.057)	(0.054)	(0.062)
Log MV Per 1000 People	0.192***	0.236***	-0.124*	-0.086	0.025
	(0.065)	(0.070)	(0.073)	(0.063)	(0.094)
Governing Party	0.094**	0.011	0.029	0.035	0.009
	(0.042)	(0.043)	(0.043)	(0.041)	(0.044)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Time Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Time Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes
Observations	877	877	877	877	877
R-squared	0.466	0.682	0.811	0.868	0.894
F-test for Joint Significance	7.530	2.870	1.021	0.943	0.403
F-test P-value	0.000	0.003	0.436	0.505	0.951

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Appendix Table 2B: Estimates of Natural Gas Rate

Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per-100 K	-0.659	0.512	0.011	-0.146	-0.220
	(0.490)	(0.399)	(0.194)	(0.221)	(0.278)
Hospital Beds Per-100 K	0.003	-0.016**	-0.007*	-0.003	-0.003
	(0.007)	(0.007)	(0.004)	(0.004)	(0.005)
Physicians Per-100 K	0.020**	0.009	0.002	0.000	-0.000
	(0.009)	(0.006)	(0.004)	(0.003)	(0.003)
Log Per Capita Regional GDP	-2.907***	-4.165***	-1.909**	-0.684	0.310
	(1.016)	(0.963)	(0.778)	(0.493)	(1.234)
Percent High School	0.445	0.407**	-0.103	-0.050	-0.106
	(0.297)	(0.168)	(0.099)	(0.050)	(0.113)
Percent College	0.590	0.233	0.432***	0.152	0.158
	(0.638)	(0.267)	(0.141)	(0.105)	(0.131)
Log Students Per Teacher	0.568	1.574	1.512**	-0.793	-0.344
	(1.642)	(1.006)	(0.723)	(0.557)	(0.587)
Unemployment Rate	-0.091	-0.071	-0.011	0.023	0.032
	(0.107)	(0.048)	(0.035)	(0.023)	(0.039)
Family Doctor	-0.145	0.159	-0.358	-0.026	0.107
	(1.105)	(0.482)	(0.378)	(0.300)	(0.316)
Log MV Per 1000 People	0.054	1.055*	-0.155	0.218	0.435
	(1.089)	(0.575)	(0.554)	(0.299)	(0.476)
Governing Party	0.267	-0.140	-0.282	0.067	0.250
	(1.017)	(0.475)	(0.299)	(0.160)	(0.209)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Time Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Time Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes
Observations	877	877	877	877	877
R-squared	0.477	0.836	0.960	0.980	0.983
F-test of Joint Significance	4.108	4.557	4.540	1.312	0.955
F-test P-value	0.000	0.000	0.000	0.233	0.494

Notes: Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively.

Appendix Table 3: Infant Mortality Rate by Source

Year	World Health Organization	United Nations	Turkey
2001	26.1	31	11.4
2002	24.2	29	10.8
2003	22.3	26	10.7
2004	20.5	24	9.5
2005	18.9	22	9.2
2006	17.4	20	8.9
2007	15.9	18	8.9
2008	14.7	16	8.9
2009	13.6	15	8
2010	12.5	14	7.8
2011	11.5	---	7.9

Sources: TUIK; World Health Organization: Child Mortality Estimates; United Nations: The State of the World's Children.
Note: We do not have data on the infant mortality rate for 2011 from the United Nations.

Appendix Table 4A: Estimates of Time Varying Observable Province Characteristics on Binary Natural Gas Indicator

Dependent Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per 100K	-0.269*	-0.028	-0.046	-0.105*	-0.103
	(0.142)	(0.071)	(0.058)	(0.062)	(0.068)
Hospitals Beds Per 100K	46.234***	0.444	-0.524	-4.537	-2.828
	(16.823)	(4.791)	(4.160)	(3.903)	(3.835)
Physicians Per 100K	32.635***	3.710*	-1.777	-0.957	-1.954
	(9.753)	(2.062)	(2.618)	(2.691)	(2.876)
GDP Per Capita	3.137***	0.320*	0.031	0.122**	0.056
	(0.699)	(0.185)	(0.065)	(0.058)	(0.046)
Percent High School	2.386***	0.438**	0.384	0.069	0.022
	(0.612)	(0.175)	(0.245)	(0.213)	(0.171)
Percent College	1.861***	0.193	0.155	0.055	0.042
	(0.487)	(0.163)	(0.154)	(0.160)	(0.135)
Students Per Teacher	-1.937**	0.311	0.206	-0.117	0.057
	(0.815)	(0.221)	(0.201)	(0.272)	(0.253)
Unemployment Rate	-0.743	-0.654*	-0.080	-0.156	0.416
	(0.594)	(0.371)	(0.324)	(0.348)	(0.362)
Family Physician Program	0.023	0.013	-0.044	-0.021	-0.026
	(0.040)	(0.040)	(0.056)	(0.062)	(0.067)
Log Vehicles PC	0.481***	0.006	-0.004	-0.000	-0.001
	(0.113)	(0.014)	(0.005)	(0.004)	(0.004)
Governing Party	0.164**	0.036	0.050	0.044	0.027
	(0.065)	(0.064)	(0.083)	(0.057)	(0.062)
Log Population	0.844***	-0.015	0.009*	0.003	0.003
	(0.201)	(0.013)	(0.005)	(0.003)	(0.003)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes

Notes: Each cell corresponds to a separate regression. Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively. Sample sizes are 797 for Hospitals Per 100K, Hospitals Beds Per 100K, Students Per Teacher, percent with college education, 400 for Physicians Per 100K ; 395 for GDP Per Capita, 636 for Percent High School, Vehicles Per Capita, and Unemployment Rate; and 877 for Family Physician Program, Governing Party, and Population.

Appendix Table 4B: Estimates of Time Varying Observable Province Characteristics on Natural Gas Subscription Rate

Dependent Variable	(1)	(2)	(3)	(4)	(5)
Hospitals Per 100K	-0.022***	-0.005	-0.000	-0.007	-0.021
	(0.008)	(0.009)	(0.013)	(0.014)	(0.015)
Hospitals Beds Per 100K	3.256**	-1.351**	-1.769*	0.887	0.989
	(1.334)	(0.655)	(0.952)	(1.183)	(1.164)
Physicians Per 100K	3.572***	-0.651**	-0.294	0.200	0.399
	(1.341)	(0.291)	(0.539)	(0.547)	(0.491)
GDP Per Capita	0.321***	0.193***	0.018	0.003	-0.004
	(0.044)	(0.040)	(0.024)	(0.043)	(0.041)
Percent High School	0.231***	0.012	-0.072	-0.006	-0.004
	(0.037)	(0.016)	(0.044)	(0.036)	(0.026)
Percent College	0.184***	0.055***	0.012	0.022	0.038
	(0.053)	(0.011)	(0.032)	(0.033)	(0.025)
Students Per Teacher	-0.069	0.042*	0.130*	-0.002	-0.005
	(0.053)	(0.023)	(0.065)	(0.029)	(0.033)
Unemployment Rate	0.013	-0.066*	0.088	-0.009	-0.034
	(0.033)	(0.036)	(0.066)	(0.066)	(0.064)
Family Physician Program	0.002	0.003	-0.012	-0.002	0.003
	(0.003)	(0.003)	(0.010)	(0.014)	(0.012)
Log Vehicles PC	0.022***	-0.003*	0.000	0.001	0.002
	(0.005)	(0.002)	(0.001)	(0.001)	(0.002)
Governing Party	0.005	-0.005	-0.013	0.003	0.012
	(0.007)	(0.008)	(0.014)	(0.008)	(0.009)
Log Population	0.064***	0.003	0.000	-0.000	-0.000
	(0.019)	(0.002)	(0.001)	(0.001)	(0.001)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Province Fixed Effects	No	Yes	Yes	Yes	Yes
Province-specific Linear Trends	No	No	Yes	Yes	Yes
Province-specific Quadratic Trends	No	No	No	Yes	Yes
Region by Year Fixed Effects	No	No	No	No	Yes

Notes: Each cell corresponds to a separate regression. Robust standard errors, clustered at the province level, are in parentheses. A *, **, or *** indicates significance at the 95%, 99%, or 99.9% levels, respectively. Sample sizes are 797 for Hospitals Per 100K, Hospitals Beds Per 100K, Students Per Teacher, percent with college education, 400 for Physicians Per 100K ; 395 for GDP Per Capita, 636 for Percent High School, Vehicles Per Capita, and Unemployment Rate; and 877 for Family Physician Program, Governing Party, and Population.